Metallurgical & technological aspects on welding of Cast iron

1.0 INTRODUCTION

Cast iron (CI) is considerably less weldable than low carbon steel. It contains more carbon and silicon than steel, with the result that cast iron is less ductile and when welded, is subjected to more metallurgical complications in both the weld metal and heat affected zone. Among the common four types of CI, nodular cast iron has the best weldability while white CI is extremely difficult to weld. Repair of defects in new iron castings represents the largest single area of application of welding of cast iron. Minor defects such as porosity, sand holes, cold shuts, washouts or shift can usually be repaired.

Most welding is done on gray cast iron. The weldability of spheroidal graphite iron is better than that of gray cast iron because, the sulphur & phosphorous contents are generally at a lower level, so that the risk of hot tearing in the weld metal is reduced. During welding, a lot of metallurgical changes appear in the microstructure of the base plate. In the region heated above eutectoid temperature, the ferrite is transformed to austenite. Fe-C equilibrium diagram is shown in figure-1. Above about 800°C, graphite starts to go into solution and simultaneously cementite is precipitated - first at the grain boundaries and at higher temperatures (i.e., with high heat input) when more graphite is dissolved, within austenite grains. At still higher temperatures, in the vicinity of weld some melting occurs. On cooling, the cementite network remains but the austenite transforms - high carbon region to martensite and low carbon region to pearlite. Thus, the heat affected zone (HAZ) of fusion welds in cast iron has a complex structure comprising re-melted regions, un-dissolved graphites, martensite, fine pearlite, coarse pearlite and some ferrite. Needless to say, this structure is very hard and brittle. If such a weld is tested in transverse tension or bending it fails through the weld boundary zone.

The size, shape and distribution of the graphite greatly influence the properties of gray cast iron. Coarser graphite flakes deteriorate ductility. The type characteristics and size of flake graphite according to AFS and ASTM graphite-flake rating chart is shown in figure-2. In general, type A graphite with random or uniform distribution is desirable in gray cast irons. Although the weldability of gray cast iron is moderately good, castings having coarse graphite flakes (below type A4) often exhibit porosity during repair welding. The porosities are confined only to the first layer on multi-layer deposits and not on the subsequent layers. An interaction of the welding arc with the coarse graphite flakes (> 1.0 inch length) may generate CO which may be the cause for such porosity formation. The appearance of porosity in the weld due to CO formation is also reported in the literatures [1].

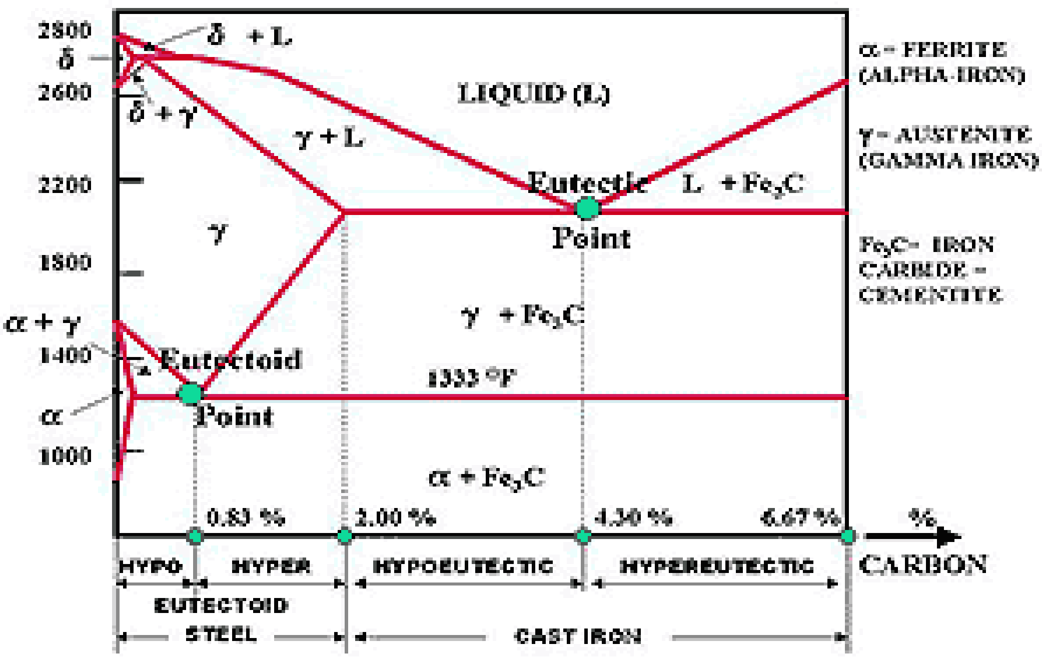

Figure-1: Fe-C equilibrium diagram

Commonly cast irons contain >2% carbon and 1-3% silicon. Specific amounts of other elements are sometimes added to achieve definite characteristics. The properties commonly sought for when cast irons are selected for a particular application are; economy, good castability even in complex forms, damping of vibrations and resistance to heat checking or heat shock. Strength is normally not a prime concern.

The common applications for cast iron are –

- housings & enclosures

- machine frames and bases
- pipe fittings
- clutch plates
- brake drums
- counterweights, etc.

2.0 CLASSIFICATION OF CAST IRONS

Cast iron are divided into four major classes based on their structure and graphite morphology – grey, malleable, nodular or spheroidal & white cast iron. The classification is shown in figure-3.

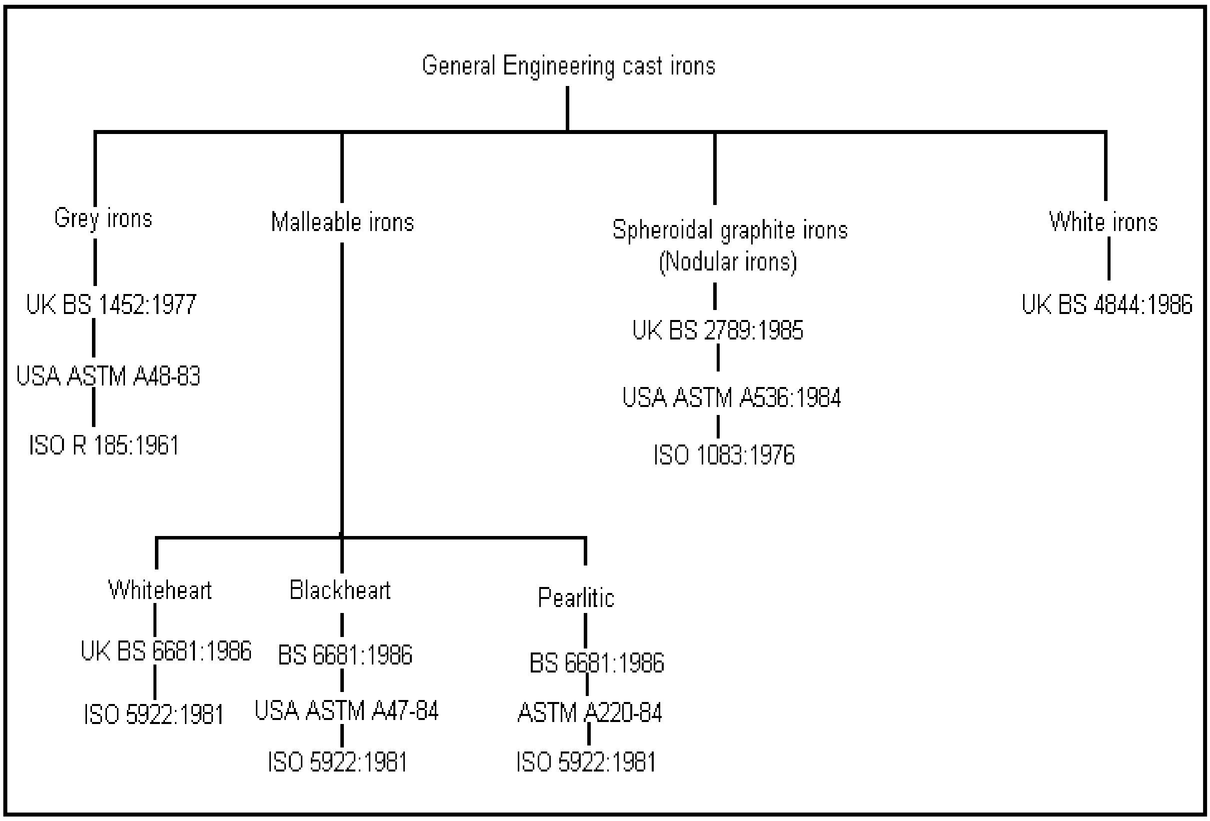

Figure-3: Classification of cast irons

2.1 Grey cast iron

Gray cast iron is by far the oldest and most common form of cast iron. As a result, it is assumed by many to be the only form of cast iron and the terms "cast iron" and "gray iron" are used interchangeably. Unfortunately the shortfall of gray iron – brittleness is also assigned to "cast iron" and hence to all cast irons. Different types of grey irons and their classifications based on the length of flake are shown in figure-2, and micro-structure is shown in figure-4.

Figure-4: Microstructure of grey cast iron

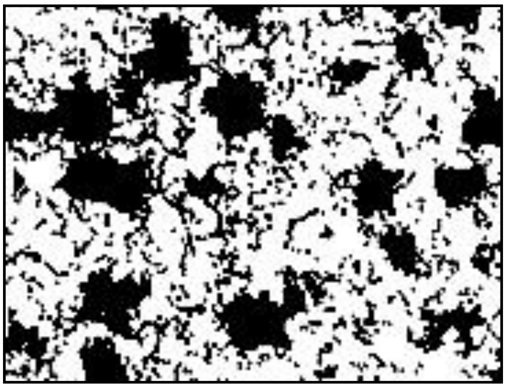

Figure-5: Microstructure of malleable cast iron

Gray iron is named because its fracture has a gray appearance. It contains carbon in the form of flake graphite in a matrix which consists of ferrite, pearlite or a mixture of the two. The fluidity of liquid gray iron, and its expansion during solidification due to the formation of graphite, has made this metal ideal for the economical production of shrinkage-free, intricate castings such as motor blocks. The presence of graphite flakes gives gray iron excellent machinability and self-lubricating properties.

However, the graphite flakes act as stress raisers which may prematurely cause localized plastic flow at low stresses, and initiate fracture in the matrix at higher stresses.

2.2 Malleable cast iron

If cast iron is cooled rapidly, graphite flakes do not get a chance to form. Instead, white cast iron (Fe_3C) forms. This white cast iron if reheated to about 930ºC for long periods of time, cementite (Fe_3C) decomposes into ferrite and free carbon. If the cooling is very slow, more free carbon is released. This free carbon is referred to as temper carbon, and the process is called malleableizing. The microstructure is shown in figure-5.

Malleable castings are divided into two main classes

1. ***Whiteheart malleable irons***

- They are high carbon white irons annealed in a decarburizing medium. Carbon is removed at the casting surface, the loss being only partly compensated by diffusion of carbon from the interior. Whiteheart castings are inhomogeneous with a decarburized surface skin and a higher carbon core

2. ***Blackheart malleable irons***

- Balckheart irons are produced by annealing low carbon (2.2-2.9%) white iron castings without decarburization. The resulting structure, which consists of carbon in a ferritic matrix, is homogeneous irrespective of section size. Mechanical properties are generally superior to those of whiteheart irons.

Malleable cast iron is used for –

- Connecting rods
- Universal joint yokes
- Transmission gears
- Compressor crank shafts
- Flanges & pipe fittings
- Valve parts
- Various marine items, etc

The advantages of malleable cast irons are – excellent machinability, ductility and good shock resistance, while the disadvantage is the shrinkage during solidification.

2.3 Nodular cast iron

Nodular or spheroidal cast iron is developed from the melt. The carbon forms into spheres when cerium, magnesium, sodium, or other elements are added to a melt of iron. The matrix of this type of CI may form pearlitic, ferritic, martensitic structures in which the carbon spheres are embedded. Microstructure of this grade is shown in figure-6.

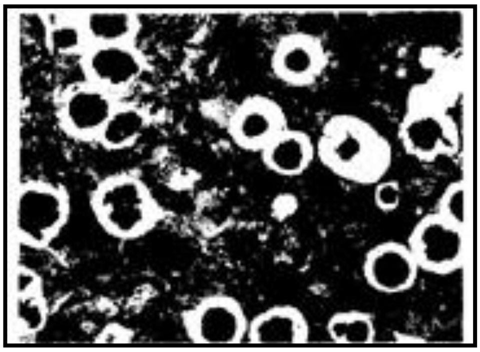

Figure-6: Microstructure of nodular cast iron.

Nodular CI has the best combination of overall properties. This grade has reasonably good ductility (often >18%), high strength (>100 ksi) and good wear resistance.

In addition nodular cast iron offers significantly low shrinkage during casting. It requires feeders that are much smaller than those used for malleable cast iron & steel. This reduced requirement for feed metal increases the productivity of nodular cast iron and reduces its material and energy requirements, resulting in substantial cost savings.

The "as-cast" use of the most common grades of nodular cast iron eliminates heat treatment costs, offering a further advantage. Nodular cast iron is used for many structural applications, particularly those requiring strength & toughness combined with good machinability. The automotive and agricultural industries are the major users of ductile iron castings. The common uses of nodular iron are -

- Crankshafts & engine connecting rods
- idler arms
- wheel hubs
- truck axles
- disk brake calipers
- suspension system parts
- power transmission yokes
- pipe lines, etc

2.4 White cast iron

White cast iron is unique in that it is the only member of the cast iron family in which carbon is present only as carbide. The fractured surface looks white so they are called white cast iron. The presence of different carbides, depending on the alloy content, makes white cast irons extremely hard and abrasion resistant but very brittle. Microstructure of white cast iron is shown in figure-7.

Another form of white cast iron is the chilled cast iron (figure-8).

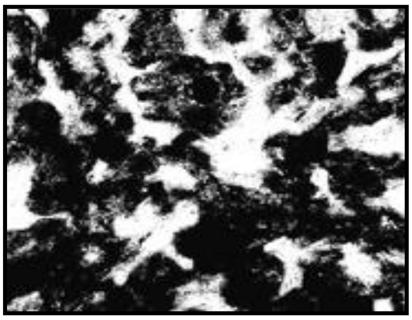

Figure-7: Microstructure of white CI

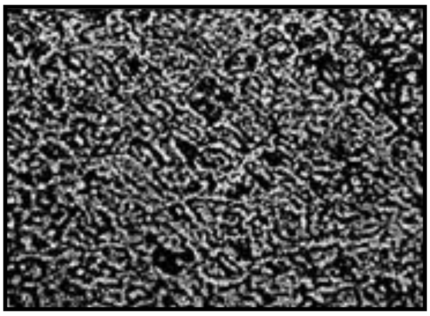

Figure-8: Microstructure of chilled CI

A chilled iron casting is produced by adjusting carbon composition of white cast iron so that the normal cooling rate at the surface is just fast enough to produce white cast iron while the slower cooling rate below the surface will produce gray iron. The hardness of the chilled zone increases with increasing carbon content.

Chromium (1-4%) is used to control the chill depth. Formation of chromium carbides increases hardness & improves abrasion resistance. Fast cooling promotes carbide formation. The hardness of chilled CI is generally due to the formation of high carbon martensite.

Chilled CI is used for railway-car wheels, crushing rolls, stamp shoes & dies, and many heavy-duty machinery parts.

2.5 Alloy cast iron

Apart from the above four conventional grades, there is one more grade called as special or alloy cast irons (shown in figure-9).

They differ from the common cast irons mainly in the higher content of alloying elements (>3%), which promote microstructures having special properties for elevated temperature applications, corrosion resistance, and wear resistance. The matrix may be - ferritic, pearlitic, austenitic, martensitic, bainitic (austempered).

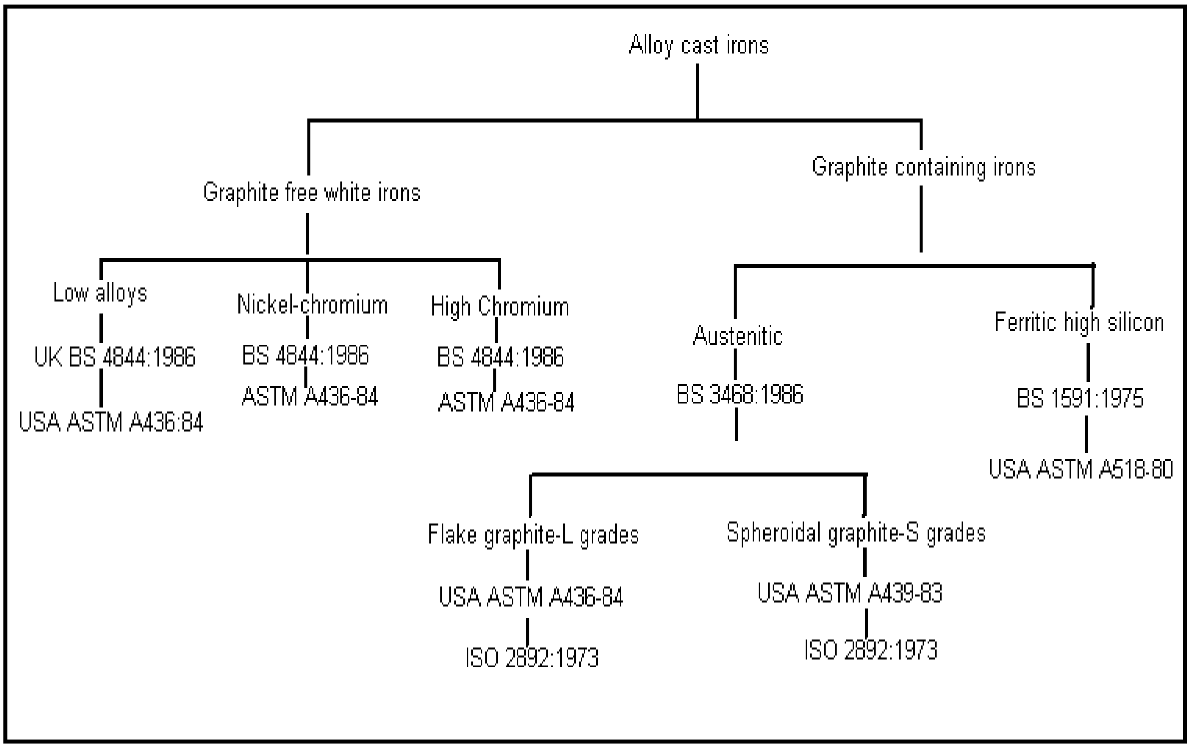

Figure-9: Classification of alloy cast irons

The mechanical properties of various grades of cast irons are shown in Table-1.

Table-1: Mechanical properties of cast iron

Type	Grade	Tensile strength, N/mm2	0.2% Proof stress, N/mm2	Elongation, % (min)	Hardness, BHN
Grey Iron BS 1452:1977	150	150	98	-	130-160
	180	180	117	-	150-180
	220	220	143	-	160-200
	260	260	169	-	180-220
	300	300	195	-	200-250
	350	350	228	-	225-275
	400	400	260	-	250-305
Spheroidal graphite (nodular) iron BS 2789:1985	900/2	900	600	2	302-359
	800/2	800	480	2	248-352
	700/2	700	420	2	229-302
	800/3	600	370	3	192-269
	500/7	500	320	7	170-241
	450/10	450	320	10	160-221
	420/12	420	270	12	<212
	400/18	400	250	18	179
	400/18L20	400	250	18	179
	350/22	350	220	22	160
	350/22L40	350	220	22	160
Whiteheart Malleable iron BS 6681:1986	W35-04	340	-	5	230 max
		350	-	4	
		360	-	3	
	W38-12	320	170	15	200 max
		380	200	12	
		400	210	8	
	W40-05	360	200	8	220 max
		400	220	5	
		420	230	4	
	W45-07	400	230	10	220 max
		450	260	7	
		480	280	4	
Blackheart Malleable iron BS 6681:1986	B30-06	300	-	6	150 max
	B32-10	320	190	10	150 max
	B35-12	350	200	12	150 max
Pearlitic Malleable iron BS 6681:1986	P45-06	450	270	6	150-200
	P50-05	500	300	5	160-220
	P55-04	550	340	4	180-230
	P60-03	600	390	3	200-250

	P65-02	650	430	2	210-260
	P70-02	700	530	2	240-290

3.0 WELDING OF CAST IRONS

Cast iron contains much more carbon and silicon therefore they are less weldable than low carbon steel. The three major areas of the cast welding applications are –

1. Repair of casting defect in foundry.
2. Repair of castings that have become damaged or worn in service.
3. To join together separately cast sections.

During welding the considerations should be given to: a) material and condition of the job at hand, b) whether to apply preheating to castings and c) whether to provide protected slow cooling.

Preheating slows the cooling rate, prevent formation of brittle structures. It also permits the whole casting to contract together with the weld material, reducing residual stresses. At the time of repair, complete removal of defects shall be ensured and provide room for satisfactory filler metal deposition with the minimum penetration.

3.1 MMAW/ SMAW electrodes

Arc welding is widely used for welding-cast-iron. The electrodes commonly used are – a) iron based, b) nickel based, and c) nickel copper based.

The consumable specifications are; AWS A5.11 (Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding) and AWS A5.15 (Specification for Welding Electrodes and Rods for Cast Iron). Often copper and copper alloy arc welding electrodes are also used. They are covered under the specification of AWS A5.6.

The compositions of these classes of electrodes are shown in Table-2.

3.2 GTAW

Gas Tungsten Arc Welding can also be used for welding cast iron (gray iron). A higher preheat is usually recommended. Filler materials in form of rods but of chemical composition similar to those used for SMAW can be used.

GTAW does not present any significant advantage over other less expensive processes.

Table-2: Classification of SMAW electrodes of cast iron

AWS Classification	C	Si	Mn	P	S	Fe	Ni	Cu	Tin	Al
Mild steel electrode AWS A5.15-90										
Est	0.15	0.15	0.6	0.04	0.04	Rem.				
Nickel based electrodes AWS A5.15-90										
ENi-CI	2.0	4.0	2.5		0.03	8	85 Min	2.5	-	1.0
ENi-CI-A	2.0	4.0	2.5		0.03	8	85 Min	2.5	-	1.0-3.0
ENiFe-CI	2.0	4.0	2.5		0.03	Rem.	45-60	2.5	-	1.0
ENiFe-CI-A	2.0	4.0	2.5		0.03	Rem.	45-60	2.5	-	1.0-3.0
ENiFeMn-CI	2.0	1.0	10.0-14.0		0.03	Rem.	35-45	2.5		1.0
ENiCu-A	0.35-0.55	0.75	2.3		0.025	3.0-6.0	50-60	35-45	-	-
ENiCu-B	0.35-0.55	0.75	2.3		0.025	3.0-6.0	60-70	25-35	-	-
Copper based electrodes AWS A5.6-84										
ECuSn-A	-	-	-	0.04-0.35	-	0.25	-	Rem.	4.0-6.0	0.01
ECuSn-C	-	-	-	0.05-0.35	-	0.25	-	Rem.	7.0-9.0	0.01
ECuSn-A2	-	1.5	-	-	-	0.5-5.0	-	Rem.	-	6.5-9.0

3.3 GMAW

Gas Metal Arc Welding is better suited to weld ductile and malleable Iron types than for gray Iron. It is however used when productivity gains are important.

3.4 Gas welding

Oxyacetylene gas welding is performed regularly with success for welding cast iron in small castings. The characteristics of the flame may be neutral, carburizing or reducing, as per the requirement. Surrounding atmosphere shall protect the work piece & tip of filler metal from air contamination. Suitable fluxes and filler material like cast iron or bronze may be selected to match the colour of the repair in the castings.

This process is performed at lower temperatures but with higher heat input than arc welding. It is used with preheat and post-weld heat treatments, and may develop less hard & brittle heat affected zone, which may be an advantage.

Oxyacetylene welding is generally applied for welding gray cast iron and ductile iron. It is not recommended for Malleable iron because it is likely to produce a wide heat affected zone of hard and brittle white iron. Gas welding process is usually considered to be slower. The composition of various grades filler wires are shown in Table-3, Table-4 and Table-5.

Table-3: Compositions (wt.%) of cast iron filler metals for oxyacetylene gas welding

Specification	Class	C	Si	Mn	Ni	Mo	P	S	Mg	Ce
BS 1453: 1972	B1	3.0-3.6	2.8-3.5	0.5-1.0	-	-	1.5 max	1.5 max	-	-
	B2	3.0-3.6	2.0-2.5	0.5-1.0	-	-	1.5 max	1.5 max	-	-
	B3	3.0-3.5	2.0-2.5	0.5-1.0	1.25-1.75	-	0.5 max	0.1 max	-	-
AWS A5.15-82	RCI	3.2-3.5	2.7-3.0	0.60-0.75	Trace	Trace	0.50-0.75	0.1 max	-	-
	RCI-A	3.2-3.5	2.0-2.5	0.50-0.70	1.2-1.6	0.25-0.45	0.20-0.40	0.1 max	-	-
	RCI-B	3.2-4.0	3.2-3.8	0.10-0.40	0.5 Max	-	0.05 max	0.015 max	0.04-0.10	0.2 max

Table-4: Compositions (wt.%) of Ni alloy filler metals for oxyacetylene gas welding

Specification and grade			Chemical Composition											
BS: 2901: 1983	AWS: A5.14-05	Trade Name	Ni	Co	Fe	Ti	Al	Mn	C	Si	Cu	S	P	Other
NA 32		Nickel 61	93.0 min	-	1.0	2.0-3.5	1.5	1.0	0.15	0.8	0.25	0.015	0	-
	ERNi-1	Nickel 61	93.0 min	-	1.0	2.0-3.5	1.5	1.0	0.15	0.8	0.25	0.015	0	0.5
NA33		Monel 60	62-69	1.0	2.5	1.5-3.0	1.3	3.0-4.0	0.15	1.3	Rem.	0.015	0	-
	ERNiCu-7	Monel 60	62.0-69.0	-	2.5	1.5-3.0	1.3	4.0	0.15	1.3	Rem.	0.015	0	0.5
		Ni-Fe 55	52-60	1.0	Rem.	-	-	0.8	0.15	0.5	-	0.02	0	-
		Ni -Rod 44	44	1.0	Rem.	-	-	1.1	0.3	-	-	-	-	-

Single values shown are maximum

Table-5: Compositions (wt.%) of Copper filler metals for oxyacetylene gas welding

Specification and grade			Composition, %											
BS 2901:1983	AWS A5.7-84	Trade Name	Cu	Pb	Al	Fe	Ni	Mn	Si	Zn	Sn	Bi	P	Other
C10			93.8 min	0.02	0.03	-	-	-	-	-	4.5-5.5	-	0.02-0.04	
	ERCuSn-A		Rem.	0.02	0.01	-	-	-	-	-	4.0-6.0	-	0.1-0.35	0.5
C11			92.3 min	0.02	0.03	-	-	-	-	-	6-7.5	-	0.02-0.4	
C13			86 min	0.007	9.0-11.0	0.75-1.5	1.0	1.0	0.1	0.2		0.003	-	
	ERCuAl-A2		Rem.	0.02	8.5-11.0	1.5	-	-	0.1	0.02	-	-	-	0.5
C22			Rem.	0.02	7.0-8.5	2-4	1.5-3	11-14	0.1	0.15				
	ERCuMnNiAl	Superton 40	Rem.	0.02	7.0-8.5	2-4	1.5-3	11-14	0.1	0.15	-	-	-	0.5

3.5 Cast iron - Brazing

Brazing is generally done with CI to CI and CI to Steel. The filler wire melting point is greater than 454˚C and bonding is facilitated through capillary action. The lower temperature copper based filler rods are used.

The major applications include; repair welding of automotive parts, agricultural implement parts, automotive engine blocks & heads, etc. The main objection may be that the weld will stand out because of the difference in color.

3.6 Cast iron - Studding

The studding process on cast iron welding is done as shown in figure-10.

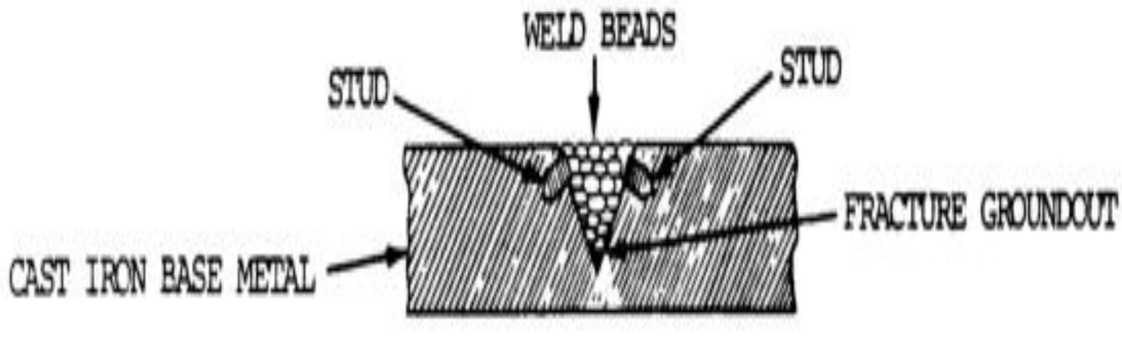

Figure-10: Schematic sketch of the stud-welding of cast irons

Drilling and tapping of holes are done over the surfaces that have been beveled to receive the repair weld metal. Then the steel studs are screwed into the threaded holes, leaving 5 to 6 mm of the stud above the surface. Welding of the studs are done and the entire cavity of the repair is filled with weld deposit.

3.7 Summary of repair welding of cast iron

The repair in cast iron welding is done through four stages, namely preparation of the job, preheating, welding and post-weld heating. The preheating is done to heat the job as well as to burn out the oil/grease from the surface.

The salient points which are to be looked into while addressing and processing the job for repair are-

1. Carry out the chemical analysis or metallurgical check of the structure.
2. Carry out grinding wheel spark test to identify the material.
3. Colour identification of freshly fractured surface – (cast steel has bright, lighter colour).
4. Conduct sound test – (gray iron gives dull, thud-like sound versus a clear ring like sound for steels).

5. To take the hardness test of the component.
6. To drill at the end of the crack to arrest growth.
7. For arc gouging, the surface after gouging should be removed by grinding or chipping prior to welding.
8. Joint groove is generally more open than for C-steel (40-45˚ bevel is normal). For thicker sections “U” groove is also used.
9. “Casting skin” – (normally GI castings contains foreign matters on surface) should be removed by grinding or chipping while joint preparation.
10. Often oil, grease, etc seep into the casting. Slow heating of the casting should be done at 370-430˚C for 30-60 minutes to burn out the oil & grease.
11. Before welding, the job shall be preheated to 250-300 ˚C to reduce the hardened HAZ.
12. Same inter-pass temperature is recommended to maintain till the completion of the welding.
13. Slow cooling after completion of welding is desired – accomplished by periodic torch heating or covering with insulating material.
14. If dimensional stability is essential, job must be stress relieved at 600-650˚C with slow cooling up to 400˚C. PWHT shall be done at 880-920 ˚C (1hr/inch).
15. ENi-CI and ENiFe-CI are the most commonly used electrodes.
16. ENiFe-CI weld is stronger & has relatively low co-efficient of thermal expansion that reduces welding stresses and improves resistance to cracking.
17. ENi-CI weld is preferred for thin section welds.
18. If maximum machinability is not of a concern (seldom it is!), better to use Ni-Fe type electrode.
19. Welding current recommended by the electrode manufacturer should be used.

20. Cast iron weld bead is somewhat more sluggish than low carbon steel weld metal. Little weaving (not greater than 3 times of the electrode diameter) or oscillation is preferred.
21. Normally 3.15mm diameter electrodes are most commonly used for slower rate of heat input.
22. Welding sequence should be such to reduce the distortion and weld stresses.
23. Often back step welding technique is preferred to minimize distortion & weld stresses.
24. Peening of the weld metal (while still hot) insure compressive stress in weld and helps to minimize distortion.
25. Peening should be done with a rounded tool with moderately intense blows.

3.8 Welding process & filler wire selection

Selection of process & consumable depends on the end-use requirements (Table-6). Application-wise selection chart for consumables is shown in Table-7.

Table-6: Characteristics-wise process selection chart

Welding Process	Penetration and dilution	Color Match	Machinability of weld and HAZ	Filler Metal
Oxyacetylene	Low	Good	Good	Grey cast iron, Nodular iron
Bronze Welding (Braze welding)	Nil	Poor	Good	Brass 41-63 Cu
MMA	Medium	Monel filler good others poor	Generally poor	Ferro nickel
MIG	Low to Medium depending on welding conditions	Poor	Generally poor	Ferro Nickel Aluminium Bronze

Table-7: Application-wise consumable selection chart

SN	Name of the Part/Component	Type
1	Cast Iron to Mild Steel – Joining	Fe-Ni
2	Gear Box Housing – Joining	Fe-Ni
3	Wagon Tippler Gear – Broken teeth	Fe-Ni
4	Pump Housing & Casing – Broken or crack	MS/ Pure Ni/ Fe-Ni
5	Bell Housing – Broken or crack	Monel
6	Isolating Valve Butterfly valve – Crack	MS/ Pure Ni/ Fe-Ni
7	Machines base & Idlers – Wear	Monel
8	Crusher Roller – Edge break	MS/ Fe-Ni
9	Sprocket Wheel – Wear	Fe-Ni
10	Piston – Wear	Pure Ni
11	Pan Cover – Crack	Pure Ni
12	Cast Iron Valve – Abrasion or Corrosion	Pure Ni
13	Cast Iron Gear – Wear	Fe-Ni/ Pure Ni

The preheat temperature selection for common welding processes is shown in Table-8 and the products of D & H Sécheron Electrodes Private Limited to conform those requirements are shown in Table-9.

Table-8: Preheat temperatures for welding of various grades of cast irons

Material	Cast iron type	MMAW, ˚C	GMAW, ˚C	Gas welding, ˚C
Ferritic	Flake	300	300	600
	Nodular	RT-150	RT-150	600
	Whiteheart malleable	RT(200˚C if high carbon core involved)	RT	600
Pearlitic	Balckheart malleable	RT-150	RT-150	600
	Flake	300-330	300-330	600
	Nodular	200-330	200-330	600

	Malleable	300-330	300-330	600

Table-9: Few D & H Sécheron-make products for cast iron welding

SN	Type	Name of the Product
1	MS	Lotherme 701
2	Monel	Lotherme-702 / D&H Monel
3	Fe-Ni	Lotherme-703 / D&H FN / LoTherme 703LN / Fenitherme / D&H 1111CI
4	Pure Ni	Lotherme-704
5	Pure Ni	Lotherme-705 / NFM

4.0 COMMON CAST IRON WELDING PROBLEMS

The major contributing factors to the cast iron welding problems are -

1. Inadequate bonding – usually matters such as incomplete penetration of the weld metal into base metal; lack of fusion between the weld metal & the base metal, or between portions of weld metal; inadequate joint geometry; etc.
2. Inclusions – these may involve the formation of oxide films; the entrapment of slag or metal/gas reaction products; etc.
3. Undercut & excessive reinforcement.
4. Metallurgical effects – undesirable metallurgical structures related to micro-segregation, hot cracking & fissures; cold cracking; gas porosity; etc.

These problems can be taken care by –

1. Increasing awareness of welding know-how and experience.
2. Right selection of welding process characteristics.
3. Adequate care for base metal defects or compositions.

4. Right consumable selection and properties.
5. Providing an appropriate environment (joint design, fit up, pre-heat & inter-pass temperature, etc) for welding.

5.0 FEW SPECIFICATIONS ON CAST IRON

The commonly used specifications for various cast iron components are listed below (Table-10).

Table-10: Various ASTM specifications related to cast iron

Standard	Description
ASTM A47	Ferritic Malleable Iron Castings
ASTM A48	Gray Iron Castings
ASTM A74	Cast Iron Soil Pipe and Fittings
ASTM A126	Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM A159	Automotive Gray Iron Castings
ASTM A247	Evaluating the Microstructure of Graphite in Iron Castings
ASTM A278	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 deg F (350 deg C)
ASTM A319	Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts
ASTM A327	Test Methods for Impact Testing of Cast Irons
ASTM A395	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
ASTM A436	Austenitic Gray Iron Castings
ASTM A439	Austenitic Ductile Iron Castings
ASTM A476	Ductile Iron Castings for Paper Mill Dryer Rolls
ASTM A518	Corrosion-Resistant High-Silicon Iron Castings
ASTM A532	Abrasion-Resistant Cast Irons
ASTM A536	Ductile Iron Castings
ASTM A571	Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service
ASTM A602	Automotive Malleable Iron Castings
ASTM A608	Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperature

ASTM A644	Standard Terminology Relating to Iron Castings
ASTM A667	Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders
ASTM A748	Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use
ASTM A823	Statically Cast Permanent Mold Gray Iron Castings
ASTM A834	Common Requirements for Iron Castings for General Industrial Use
ASTM A842	Compacted Graphite Iron Castings
ASTM A874	Ferritic Ductile Iron Castings Suitable for Low-Temperature Service
ASTM A888	Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications
ASTM A897	Austempered Ductile Iron Castings
ASTM A942	Centrifugally Cast White Iron/Gray Iron Dual Metal Abrasion- Resistant Roll Shells

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ACKNOWLEDGEMENT

The author acknowledges the assistance & input received from Mr. TJP Rao for compilation of this document.